# User's Guide

# TPS*X*

*for Windows*

## Thermal Protection Systems Expert and Material Properties Database

**Version 1.1**

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# Notices

## Disclaimer

A sincere effort has been made to provide accurate material information. However, mistakes can be made and any consequences of such errors are solely the responsibility of the user of this program. No guarantees or warranties are provided for either the database information or software. The program and data are distributed "as is".

## Distribution

NASA Ames Research Center distributes the TPS*X*. Distribution and access to the code is restricted. If a NASA developed computer code is not available through the NASA computer code dissemination center (COSMIC), NASA Management Instruction 2210.2B will permit its distribution under certain conditions.

For further information about obtaining TPS*X*, contact:

Mail: TPS*X* Support
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M/S 234-1
Moffett Field, CA 94035-1000
FAX: (650) 604-0487
E-Mail: tpsx-support@asm.arc.nasa.gov
WWW: http://asm.arc.nasa.gov/tpsx/

## Credits

TPS*X* is produced and maintained by the engineers and scientists of the Thermal Protection Materials and Systems (ASM) Branch at NASA Ames Research Center. This program is the result of a project to compile, maintain and provide easy access to the large amount of material property data used by STM in the development of spacecraft thermal protection systems. The following people have contributed to the program:

| | |
|---|---|
| Dr. Daniel Rasky | STM Branch Chief and TPS*X* project director |
| Thomas Squire | concept development, programming and documentation |
| George Hartlieb | computer systems support and consulting |
| Mark Gilbert | database compilation, programming and documentation |
| Marilyn Murakami | secretary; systems, software and moral support |

## Acknowledgments

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# Introduction

## What is TPS*X*?

TPS*X* is a Windows database program for organizing and accessing the properties of advanced thermal protection system (TPS) materials. The program provides an easy user interface for retrieving, displaying, graphing, printing and saving material properties in a variety of formats. The database includes thermal, mechanical, ablation, chemical and electrical properties. A description of each material, including references, common applications and points of contact, are also provided. TPS*X* also contains photos and sketches of some materials. Users can create their own databases from scratch, or by copying materials from the databases that ship with TPS*X*. The two databases that ship with TPS*X* are stored in a binary format and cannot be altered by the user, this is done in order to maintain the integrity and consistency of the data.

TPS*X* is distributed with two material databases; 1) materials used and/or developed by the Thermal Protection Materials and Systems (ASM) branch at NASA Ames Research Center; and 2) the database compiled by Johnson Space Center (JSC) [*].

In addition, TPS*X* includes two "built in" material databases. These are: a searchable JANAF database of chemical species, and a searchable solid species database currently containing property information on over 500 refractory materials compiled by Los Alamos Laboratory[†] . These two databases have their own specialized windows that allow the user to lookup up property information.

TPS*X* has several basic tools to aid in thermal protection system design. These include: a periodic table of elements with thermal properties, a list of useful physical constants, a units converter; and costing analysis worksheet.

TPS*X* allows users to save material property data in formats suitable for a number of computational tools, including CMA, ASC, COSMOS/M and SINDA. The program handles all the necessary units conversions, so that the information can be cut directly into an input data deck.

Future enhancements to TPS*X* will include: additional material databases compiled by other NASA facilities and private companies; a simple 1-D thermal analysis module to estimate material temperatures under a given heating condition; a module to predict the heating conditions for atmospheric entry trajectories used in the design of thermal protection systems; and porting the program to other computer platforms.

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* "Thermal Protection Materials: Thermal Physical Property Data", D. Curry, S.D. Williams, NASA Reference Publication 1289, December 1992.

† "Thermal and Other Properties of Refractories", Technical Report Program No. R056, Dwayne T. Vier, Los Alamos Scientific Laboratory of the University of California, LA-5937-MS, April 1975.

# Getting Started

## Installation

Before using TPS*X* it must be properly installed. Refer to Appendix A: TPS*X* Installation and System Requirements for instructions.

## Program Overview

TPS*X* consists of a "desktop" and a set of specialized data windows for displaying material data and other information. You use the different data windows depending on the type, and format, of the information you wish to view. There are two basic types of windows; material data windows and supplementary data windows. The material data windows display information about the material selected by the user. The supplementary data windows are independent of the material database and provide access to the JANAF database, solid species data, periodic table, etc. All the windows may be "open" at the same time, although this makes the desktop a bit cluttered. Many of the windows can be resized or maximized, and all of them can be minimized into icons at the bottom of the TPS*X* desktop. Most of the reference information, material listings, and graphed data, from the application, can be copied and pasted into other documents. Printer output is also supported by many of the windows.

## Quick Start

This section will allow you to immediately get started using TPS*X* without extensive knowledge of all of its features. Each aspect of the program will be fully explained later in the document. Follow the instructions below and refer to the Help menu within the application if you have further questions. *This tutorial assumes you have completed the installation as described in Appendix A.*

Starting TPS*X*

As a brief tutorial you'll examine the material properties for AFRSI blanket insulation. Start TPS*X* by double clicking the TPS*X* icon in the TPS*X* program group. The TPS*X* "splash" window will be displayed while the program is loading. The Ames material database will automatically be loaded and the database banner will be displayed; you will need to click "OK" to close this window and continue. You'll notice that the Information Window is now opened automatically and that the first material in the group is displayed.

Before we move on, let's take a quick look at the TPS*X* Desktop from top to bottom. The title bar at the top of the screen displays the name of the current material database, in this case the Ames TPS Materials. Below that is the main menu bar, which provides access to all the functions of TPS*X*. Those menu options which apply to the active data window will be available, while those which are not appropriate will be "grayed out". Below the menu bar is the Toolbar, which consists of the two drop-down list boxes for Material Type (left box) and Material Name (right box), and the Button Bar. The Button Bar provides quick access to the data windows; clicking on an icon opens the associated window or brings it to the top of the desktop. The space below the Button Bar is the workspace area that contains the data windows. At the bottom of the screen is a message area that provides hints about using the active data window.

Now click on the Material Type drop-down list box in the Desktop Toolbar to display a list of the types of materials available in the Ames database. AFRSI is a flexible, reusable blanket insulator, so choose "Flexible Blankets" from the list. The first material in the list of Flexible Reusables is now displayed in the Information Window. Now, click on the Material Name drop-down list box to display the list of flexible, reusable insulator materials. If you don't see AFRSI, use the mouse to scroll down the list using the scroll bar at the right of the list box. Click on "AFRSI Blanket".

Using the Information Window

TPS*X* will "fill in" the spread sheet in the Information Window. This shows all the properties for the material at standard temperature and pressure. The text box at the bottom of the Information Window will list a brief description of the material, references for the properties and a point of contact where

appropriate. If not all the information is visible, use the scroll buttons to see the rest of the window. If you wish to obtain a hard copy of this information select the "File Print..." menu option.

Using the Picture Window

There are several pictures associated with the AFRSI material. You'll notice that the Picture Window was opened automatically, displaying one of the pictures. You can see a list of pictures for the AFRSI by clicking on the Picture drop-down list box in the Picture Window's Toolbar. You have the option to view pictures automatically or not. For more information see the "Show Picture" section in the "TPS*X* Main Menu" chapter. If the "Show Picture" option is not selected, you can open the Picture window from the "View" menu or by clicking on the Picture button in the Desktop Toolbar.

Using the Spread Sheet Window

Now examine the thermal conductivity of the AFRSI using the Spread Sheet window. You can open the Spread Sheet window either by double-clicking on the property name in the Information Window, selecting the "Spread Sheet Window" from the "View" menu, or click on the Spread Sheet button on the Desktop Toolbar. Click on the "Property" drop-down list box in the Spread Sheet window to get a list of property data available for the AFRSI. Click on "Thermal Conductivity" and the pressure and temperature dependent conductivity will be displayed. At this point it's easy to get a plot of the conductivity by either selecting "Graph Window" from the "View" menu or clicking on the Graph button on the Desktop Toolbar. The conductivity will be plotted as a function of temperature and, parametrically, as a function of pressure. The drop-down list box in the Graph window will display a list of those properties that can be graphed (i.e., those which are a function of at least one independent value).

Using the Code Interface Window

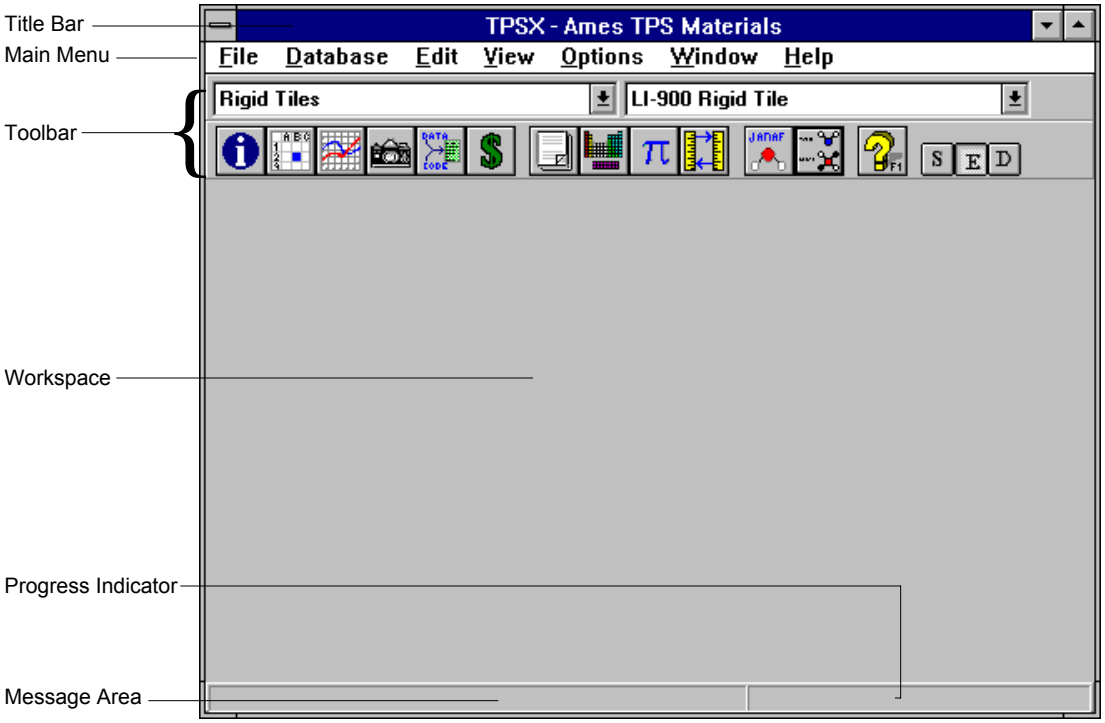
As a final step, you'll create a material property input table for the COSMOS/M finite element code. Open the Code Interface window, either from the "View" menu or by clicking the code interface button in the Desktop Toolbar. Now click on the "Program" drop-down list box in the Code Interface window to get a list of codes with which TPS*X* will interface. Select COSMOS/M. To create the code interface file using the default settings, click on the "Generate" button. You are informed, through a Warning message, that not all of the properties normally included in a COSMOS/M finite element thermal/mechanical analysis are in the database for the AFRSI material. The program has created in input file in spite of the warning, but has commented out those properties that it could not find in the database. Click on the "OK" button and you will see input file in the text area at the bottom of the window. The text in this window is fully editable, so you can make changes before saving or printing it. If you wish to change the temperature range of the properties, click on the up and down arrows in the "Temperature Range" section of the Code Interface Window. For materials, like the AFRSI, which are pressure dependent, you can also select the pressure value for the property table, since codes like COSMOS/M do not directly allow for pressure dependent properties. You'll see you can also change the thickness of the blanket, the units system and other options. These are described completely in following sections.

Conclusion

This has given you a brief tour of the material data windows. Go ahead and experiment with these and the supplementary data windows. There is no way to harm the program or data files, so don't hesitate to just fool around.

## TPS*X* Desktop

The desktop is the main TPS*X* user interface. It contains the data windows and displays the TPS*X* main menu. It also provides a toolbar for quick access to the various windows. Selections of material type and name are made on this window using the drop-down list boxes. Supplementary or material data windows are also accessed from the desktop by clicking on the appropriate button or by selecting it from the Desktop Menu View item.




TPS*X* Desktop

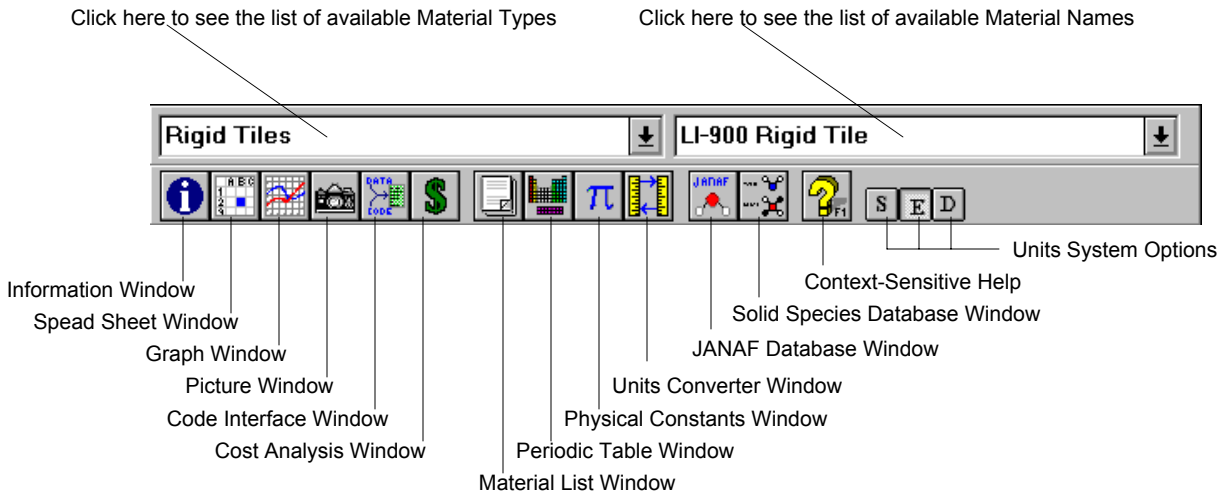
The title bar at the top of the desktop displays the name of the active material database. It also contains the standard Window control buttons.

### Main Menu

The main menu provides access to all the functions of TPS*X*, except for actually choosing a material type and name. The function of the menu options depends on which window is "active" or selected in the workspace. Those options which are appropriate for the window will be available, while the others will be "grayed out". See the chapter "TPS*X* Main Menu" for a complete description of the menu options.

### Toolbar

Below the menu bar is the desktop Toolbar, which consists of the drop-down list boxes for material type and name, and the Button Bar which allows quick access to the data windows.




TPS*X* Toolbar

The materials in a database are grouped by type. The "Material Type" drop-down list box displays these types for the active database. The types listed here remain constant while using the particular database. When a new type is selected, the data windows will be cleared and a new list of material names will be displayed. Within each type the "Material Name" drop-down list box displays the actual names of the materials. Selecting a name here will automatically bring up the Information Window with a summary of the material properties. Any other open Material Data Windows will, likewise, display the selected material properties.

The Button Bar provides the quickest access to the data windows. Clicking once on a button will open the associated window, or bring it to the top of the workspace if already opened. The group of buttons on the left represent the Material Data Windows. The next group of four buttons represent the Supplementary Data Windows. The third group of two buttons represent the built-in databases for the JANAF data and the refractory materials data. The context-sensitive help button is next; when clicked, the TPSX help file will be opened to the section corresponding to the active window. The last group of three buttons are used to select the units system for displaying material properties; "S" for SI, "E" for English, and "D" for the default values. The default values are whatever units were used to enter the data and vary from material to material.

**Workspace**

The majority of the desktop is occupied by the workspace. Here is where the data windows will be displayed, using the conventions of the Multiple Document Interface (MDI); similar to many Windows applications. The data windows can be moved around the workspace, maximized or minimized. When minimized, the windows will appear as icons at the bottom of the workspace.

**Message Area**

At the bottom of the desktop is a small message area. The messages displayed here indicates which window is "active and provides a brief description of the function of the active window.

**Progress Indicator**

Next to the message area is the Progress Indicator. When TPS*X* is working and cannot be interrupted, this indicator will show how much of the task has been completed using a sliding bar which fills the indicator as the task progresses. While the progress indicator is active, all other functions will be disabled.

## The Material Data Windows

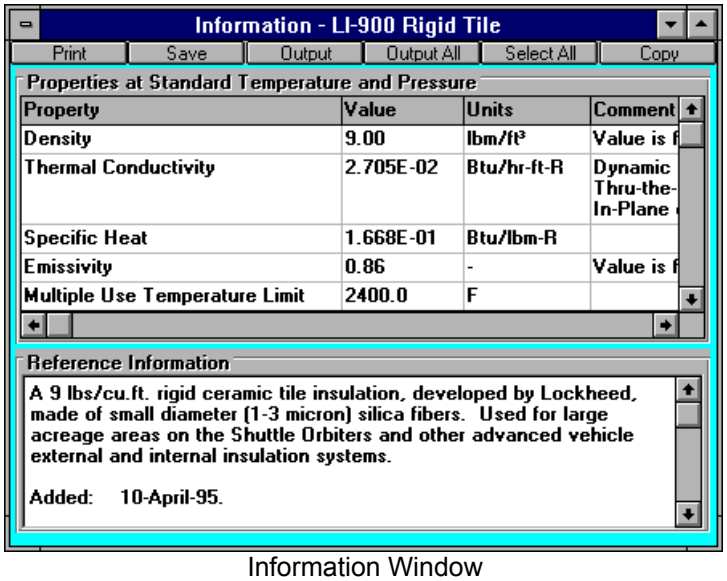
TPS*X* displays information about material properties in a number of Material Data Windows. Each window displays the information in a different form. The data in any window corresponds to the selected material name in the Material Name drop-down list box. These windows can be opened by selecting the appropriate item in the "View" menu or by clicking on the corresponding button in the Toolbar.

### A Note About Units

A major convenience of TPS*X* is its built-in units conversion. Material properties can be displayed in one of three separate units systems. These are accessed through the "Options Units" menu item, and are "SI", "English" and "Default". A check by the name in the menu indicates which system is active. The "pushed in" units button on the Button Bar also indicates the active units system. The SI and English settings are self explanatory, while the "Default" setting displays properties in whatever units happen to be used in the database. Selecting a different setting automatically converts the properties in any open window into the new system. This setting is "remembered" by TSP*X* when the program exits; so the next time the program is started the last selected units system will be active.

### Information Window

The Information Window displays general information about the selected material. This window opens automatically when TPS*X* is started or when a new material name is selected. The material properties, at room temperature and pressure, are displayed in a spread sheet format. The scroll bars can be used to move around in the spread sheet to dispaly the property, units and any comments regarding the properites.



Information Window

A scrolling text box at the bottom of the window includes a description of the material, a list of references and a point of contact for more information. The text in this box can be selected and copied to the Windows Clipboard or printed.

The Information Window contains a button bar for easy access to certain functions. These functions are also available from the main menu.

The "Print" button will send a pre-formatted report to the selected printer. This report will contain all the information in the window.

The "Output" button will open the text Output Window (described later) and create a brief report listing all the material properties at standard temperature and pressure, a description of the material, references and point of contact. The report can be edited, printed or saved from the Output Window.

The "Output All" button performs a similar function to the "Output" button be creates a more complete report listing *all* the properties in the database for the active material. Both of these reports will list properties in the units system selected in the "Options Units" menu choice. If the units system is changed the report will have to be recreated, by clicking one of the output buttons, to reflect the change.

The "Select All" button selects all the text in the text box. And the "Copy" button will copy any selected text in the text box to the Windows Clipboard.

A time-saving feature of the Information Window is that by double-clicking on any property name in the list, the Spread Sheet Window (described below) will open and display all the data associated with that property.

**Spread Sheet Window**

The Spread Sheet Window displays all the data for a specific property for the selected material in a spread sheet format. A drop-down list box in the Spread Sheet Window provides a complete list of all the material properties available for the selected material. Selecting one of the properties will display it in the spread sheet. Properties which are a function of at least one independent variable are listed in two or more columns.

The data in the Spread Sheet Window *cannot* be altered or edited, this window is strictly for display of the properties. However, it can be copied to the clipboard, printed or saved to a separate file.

If the property displayed in the Spread Sheet Window is a function of one or more independent variables, then opening the Graph Window (either from the "View" menu or by clicking the Graph button in the Toolbar) will automatically display a graph of the property.

Some material properties have additional descriptions or caveats. In such cases when that property is selected in the Spread Sheet Window a "Note" button will be visible. Clicking on this button opens a small window with a brief discussion of the property as it relates to the selected material. The text of these notes is also listed in the output when either of the "Output" options are used from the Information Window. *These notes often include very important information regarding the source of the data and its proper use.*

Spread Sheet - LI-900 Rigid Tile

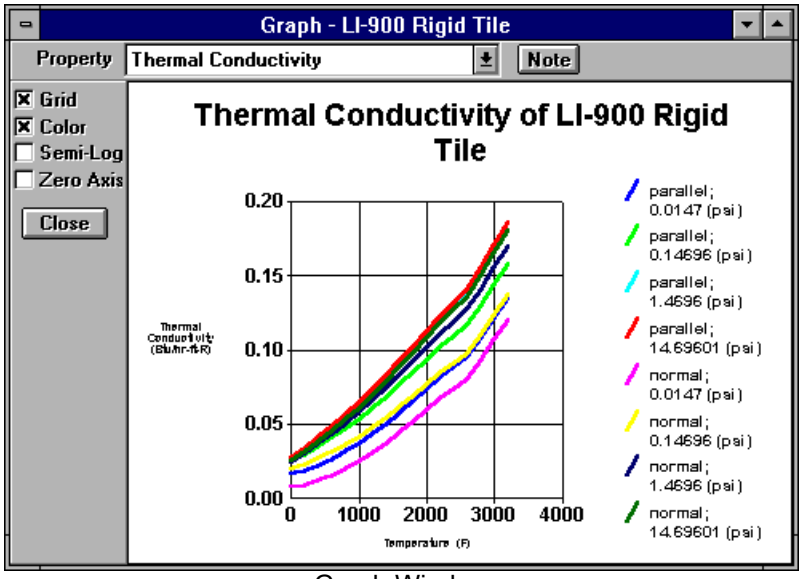
Property: Thermal Conductivity | Note

| | Direction | Pressure (psi) | Temperature (F) | Thermal Conductivity (Btu/hr-ft-R) |
|---|---|---|---|---|
| 1 | parallel | 0.0147 | 0.0 | 1.612E-02 |
| 2 | parallel | 0.0147 | 200.0 | 1.865E-02 |
| 3 | parallel | 0.0147 | 400.0 | 2.220E-02 |
| 4 | parallel | 0.0147 | 600.0 | 2.624E-02 |
| 5 | parallel | 0.0147 | 800.0 | 3.112E-02 |
| 6 | parallel | 0.0147 | 1000.0 | 3.683E-02 |
| 7 | parallel | 0.0147 | 1200.0 | 4.326E-02 |
| 8 | parallel | 0.0147 | 1400.0 | 5.029E-02 |
| 9 | parallel | 0.0147 | 1600.0 | 5.779E-02 |
| 10 | parallel | 0.0147 | 1800.0 | 6.556E-02 |
| 11 | parallel | 0.0147 | 2000.0 | 7.341E-02 |
| 12 | parallel | 0.0147 | 2200.0 | 8.111E-02 |
| 13 | parallel | 0.0147 | 2400.0 | 8.844E-02 |

Spread Sheet Window

**Graph Window**

The Graph Window displays a specific property for the selected material in a graphical format. This window can, necessarily, only display property data which is a function of one or two independent properties (e.g., thermal conductivity as a function of pressure and temperature). A drop-down list box provides a complete list of all the material properties for the selected material *which are a function of at least one independent variable*. Properties which are a function of one independent variable will be graphed as a single curve with the property measured along the ordinate and the independent value along the abscissa. Properties which are a function of two variables are plotted parametrically with two or more curves on the plot, each representing a different level for the parametric independent value.



Graph Window

The graph image can be copied to the Windows Clipboard (using the Edit menu), saved as a Windows Metafile or printed.

With a plot displayed in the Graph Window, opening the Spread Sheet Window (either from the "View" menu or by clicking the Spread Sheet button in the Toolbar) will automatically display the spread sheet for the currently selected and graphed property.

The Graph Window can be resized, maximized or minimized. Before saving or copying the graph image, it is a good idea to resize the image to roughly the size you will need. Metafiles can be rescaled when cut into another application, but they generally look better when left at the original size.

As with the Spread Sheet Window, a "Note" button will be visible if there is additional information about the property selected.

On the left side of the Graph Window are check boxes for several options. These options are also available from the Options menu.

- "Grid" will turn the grid on or off
- "Color" will switch between a graph with colored lines to one with black lines and symbols
- "Semi-Log" will switch the ordinate from a linear to a log scale (only appropriate if the data does not pass through zero)
- "Zero Axis" will rescale the plot to so that the vertical scale starts at zero

**Picture Window**

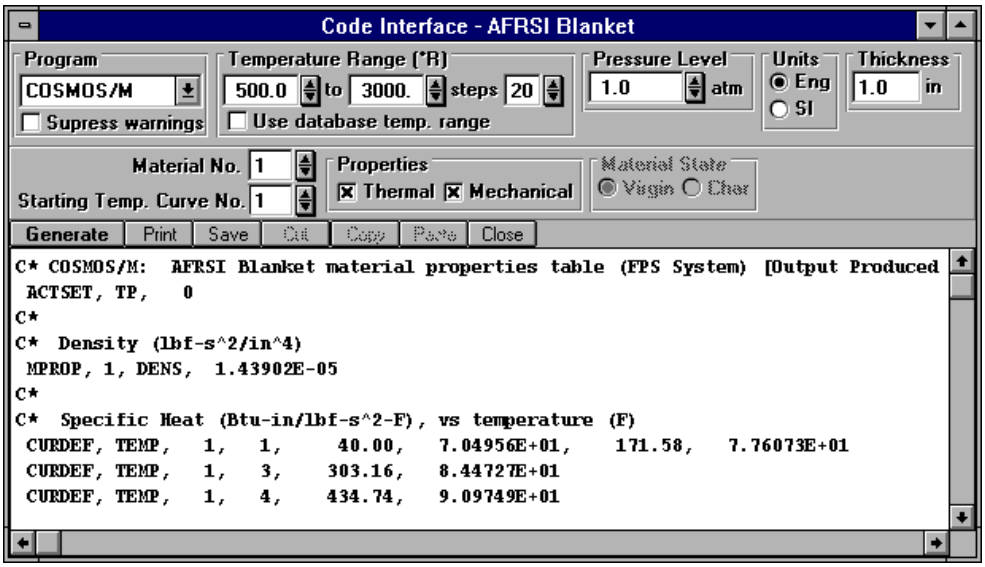
The Picture Window displays a photo or drawing of the selected material *if one is present in the database*. Many materials do not have a picture. If a picture is available it will be displayed automatically when the material is chosen from the Desktop's Toolbar and if the "Show Picture" option is checked in the "Options" menu. It can also be opened from the "View" menu or by clicking the Picture Button on the Desktop's Toolbar.

If one or more pictures is available for the selected material, they will be listed in the drop-down list box in the Picture Window's Toolbar. Using the Edit menu the picture can be copied to the Windows Clipboard and pasted into another application.

### Code Interface Window

The Code Interface Window provides a link between TPS*X* and several engineering analysis tools by formatting the necessary material properties for input into the codes. The interfaces are programmed to know just what material input the individual codes require and in what units. The interface generates the necessary code in the window's text area, where it can be copied and cut into the input deck of the corresponding code.

The Code Interface Window has a drop-down list box naming the programs for which filters are




Code Interface Window

available. Selecting any of the names and clicking on the "Generate" button will produce a listing of the necessary material property input in the window. To create the correct input for the selected code, some specialized inputs for each code are required. These inputs will appear in specialized tool bars when the code is selected from the list box. Inputs required by all the codes appear in the top toolbar in the Code Interface Window.

Interfaces are available for the following codes:

**ASC** The ABRES (Advanced Ballistic Re-Entry System) Shape Change Code. A computer program developed at Acurex Corporation to predict the thermal response of ablating heat shield materials during hyper-sonic atmospheric reentry. The Code Interface will create the temperature dependent material property table and the B' table (if the data is available).

**CMA** The Charring Material Ablation code. A computer program developed at Acurex Corporation to model the 1-D thermal response of charring/ablating materials. The Code Interface will create the temperature dependent material property table (for the primary ablating material) and the B' table (if the data is available). Note that this is *not* a complete CMA material input, additional information will be required to make the input complete.

**COSMOS/M** A finite element structural and thermal analysis system created by Structural Research and Associates Corporation. The Code Interface will create thermal and mechanical property inputs required to do most analyses.

The COSMOS/M interface creates a file which can be read into a model using the "File" command within COSMOS. Two additional inputs, available from the COSMOS/M Options Toolbar (shown below), are required to create this file. These are the material number and starting temperature curve number. When COSMOS/M

is selected in the code drop-down list box, these additional entries will become visible. The "material number" is the value that will be assigned to the material in the input file. The "starting temperature curve number" will be used to define the first of any necessary temperature curves which will be associated with temperature dependent properties. Additional curves will be incremented by 1. The tool bar also allows the user to choose which types of properties to include; thermal, mechanical or both. For ablating materials, the user has the choice to create a virgin or char property output.


COSMOS/M Options Toolbar

**SINDA 85** A lumped parameter, finite difference thermal/mechanical analysis program. The Code Interface will create thermal and mechanical property inputs required to do most analyses.

The SINDA 85 interface requires additional inputs available from the SINDA 85 Options Toolbar (shown below). Each property requires an array number that identifies it in the analysis, the starting array number can be chosen and each additional array will be incremented by 1. The SINDA input can be formatted by lines to reduce the length of the file, or by columns to make reading the input easier; this option is available from the toolbar. The toolbar also allows the user to choose which types of properties to include; thermal, mechanical or both.


SINDA 85 Options Toolbar

In addition to the specific inputs required for certain code interfaces, the main Toolbar includes options available to all the interfaces. The "Temperature Range" selections set the range for the temperature dependent properties. Clicking on "Up" and "Down" buttons, or entering values into the boxes, sets the minimum and maximum temperatures to include in the output. Selecting the "Use database range" option will create a table with temperature entries that correspond to the actual database range. When this option is not checked, TPS*X* will interpolate property values for the requested temperature range.

There is also a button that sets the pressure level for the output data. Most codes, like ASC and CMA do not accept pressure dependent properties so a pressure level must be selected and the properties will be interpolated for that value.

An option for the units system is also available. "SI" uses the standard SI units and "Eng" uses a $lb_m$, inch, seconds system. The COSMOS/M program uses a non-standard set of English units, selecting the "Eng" option will format the COSMOS/M output using this system.

Some materials, like insulating blankets, have properties dependent on the thickness of the material. In these cases, the "Thickness" input box will be enabled and a value greater than zero must be entered *in inches*.

The database for a particular material may not contain all the information necessary to create a complete property table for the selected code. If this happens, a warning message is displayed indicating the missing information. Checking the "Suppress warnings" prevents them from being displayed.

Additional editing options are available from the toolbar in the Code Interface Window. These can be used to edit the input before saving it to a file, copying to the Clipboard or printing.

## Cost Analysis Window

The Cost Analysis Window provides a means for determining the cost per flight of a given insulation material. The analysis is designed for evaluating the cost associated with a reusable vehicle carrying payloads into orbit. It is based on an analytic expression for a life cycle cost parameter ($\bar{\$}$) developed by Dr. Daniel Rasky*, and is defined as:

$$\bar{\$} = \frac{1}{N_f}[C_{pur} + C_{per}\sum h_{inst}]$$
$$+ \frac{(N_f - 1)}{N_f}\left\{C_{pur}\left[f_{repl} + \frac{1}{N_f}\,\mathrm{int}\left(\frac{N_f}{R_{lim}+1}\right)\right] + C_{per}\sum h_{rep}\right\}$$
$$+ f_{pay}\cdot W_{area}\cdot C_{pay}$$

where

$\bar{\$}$ = Dollar - bar; \$/ sqft / flight

$N_f$ = number of flights

$C_{pur}$ = unit area TPS purchase costs

$C_{per}$ = personnel hourly costs

$\sum h_{inst}$ = sum of installation task times

$f_{repl}$ = replacement fraction per flight

$R_{lim}$ = reuse flight limit

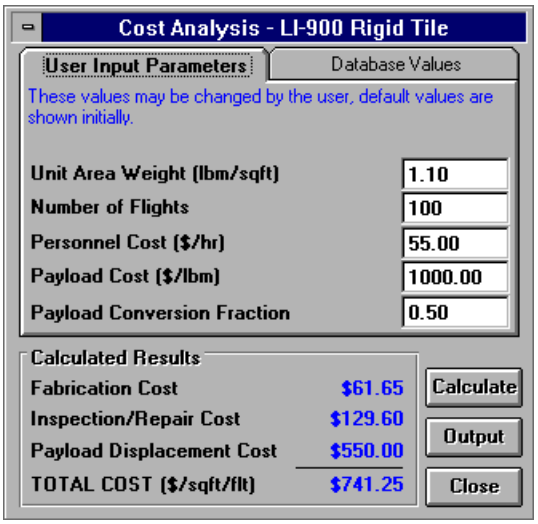
$\sum h_{rep}$ = inspection / repair task times

$f_{pay}$ = payload conversion fraction

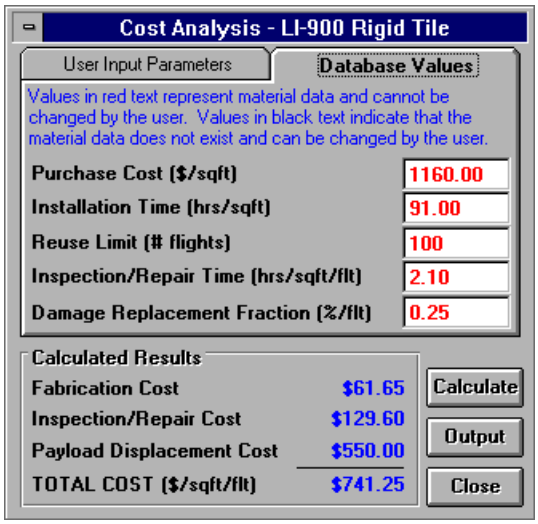
$W_{area}$ = TPS unit area weight

$C_{pay}$ = payload cost to orbit

The parameters in the expression are divided into two types; user supplied values and material dependent values from the database. Each of these sets is displayed on a separate tabbed form in the Cost Analysis Window.




Cost Analysis Window: *User Inputs*




Cost Analysis Window: *Fixed Inputs*

* Rasky, Daniel, J., "Thermal Protection Systems for Future Reusable Launch Vehicles," NASA TMX, January, 1996.

The User Input Parameters can be changed by the user, although default values are supplied. The user parameters are:

**Unit Area Weight** — The weight per unit area of insulation. This is typically a property of the material but certain design aspects may change the number (e.g., blanket thickness). It should be changed with caution.

**Number of Flights** — This is the total expected life cycle of the vehicle.

**Personnel Cost** — The hourly wage for workers installing and repairing the insulation.

**Payload Cost** — The overall cost of putting each pound of payload into orbit.

**Payload Conversion Fraction** — This represents the ratio of payload weight lost for every unit weight of insulation, e.g., a value of 0.5 indicates that for every 2 pounds of insulation added, 1 pound of payload capacity is lost.

The Database Value supplied by the program cannot be changed by the user. However, if the corresponding data does not exist in the database, then the numbers will appear in black instead of red and the user is allowed to change these entries. Currently, cost data exists for only a few of the Ames materials. For those materials without cost data the user can change the following parameters:

**Purchase Cost** — The cost per unit area of the insulation.

**Installation Time** — Time to install each unit area of insulation.

**Reuse Limit** — Maximum number of flights the material can reasonably be expected to survive.

**Inspection/Repair Time** — Time required to inspect and repair the insulation after each flight.

**Damage Replacement Fraction** — The fraction of insulation that can reasonably be expected to have to be replaced after each flight due to damage.

The cost numbers are recalculated when the "Calculate" button is pressed or by hitting the "Enter" after entering a value in any of the fields. The result shows the total cost of the insulatoin per flight as the sum of the three major cost catagories; Fabrication Cost, Inspection/Repair Cost, and Payload Displacement Cost. The "Output" button will create a short report of the cost analysis in the Output Window.

## The Supplementary Data Windows

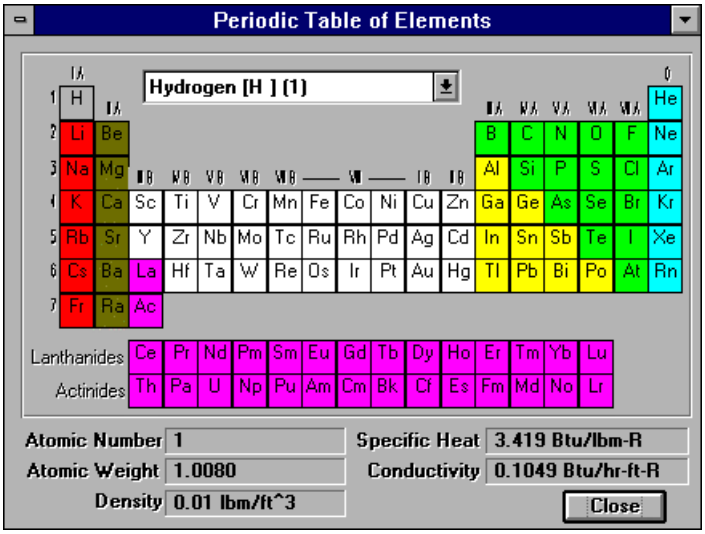
Additional information is available in TPS*X* through the Supplementary Data Windows. The data provided through these windows is of a general nature, related to engineering and material science. These windows can be opened by selecting the appropriate item in the "View Other" menu or by clicking on the corresponding button in the Toolbar.

### Material List Window

The Material List Window is a supplementary data window that lists all the material types and names in the current database. Along with the names is a summary of each material. The contents of this window cannot be altered or edited, but the text can be selected and copied to the Clipboard or saved as a file.

### Periodic Table of Elements Window

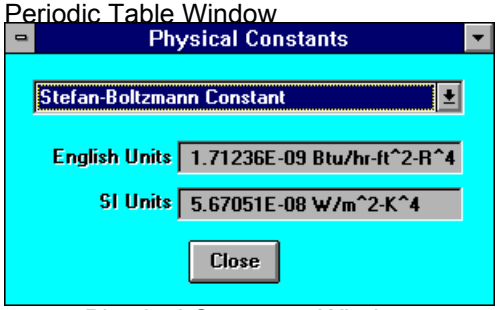
This window presents a periodic table of the elements. Clicking on any element box will display information about the element in the data boxes at the bottom of the window. These properties are at room temperature and pressure. Alternately, the elements can be chosen from the drop-down list box at the top of the window.



Periodic Table Window

### Physical Constants Window

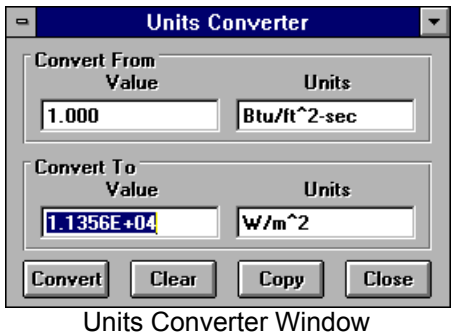
This window provides a drop-down list of useful physical constants in both SI and English units. Select a constant from the list and its value will be displayed in the boxes. The values can be selected with the mouse then copied into the Windows Clipboard using the "Edit Copy" menu item.



Physical Constants Window

### Units Converter Window

The Units Converter Window provides a quick way to convert any unit to any other, dimensionally similar, unit. To convert units, enter the numeric value and units to start with into the appropriate boxes. Then enter the units you want to convert to in the "Units To" box and click "Convert." The new value in the new units will be displayed in the "Value To" box. If you do not enter a value into the "Value From" box, the Converter will use 1.0 and the "Value To" box will display a conversion factor for converting to the new units.



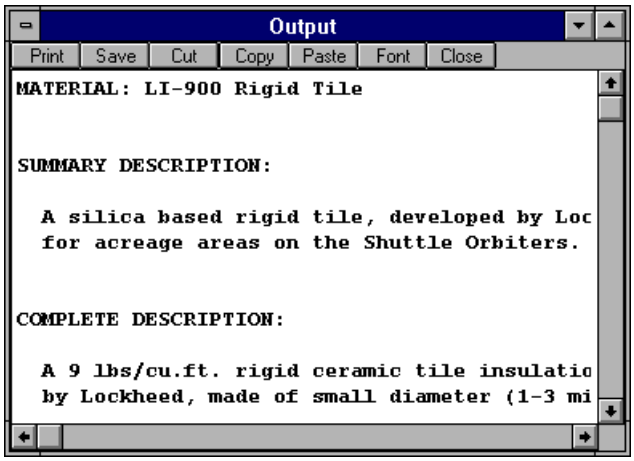
Units Converter Window

The units must be entered in a specific format. All units in the numerator must appear to the left of the slash "/" symbol and all units in the denominator must appear to the right. Within the

numerator and denominator, individual units must be separated by a dash "-". Powers are indicated using the caret "^" symbol. A warning will be displayed if the units are dimensionally consistent. The converter understands most standard unit abbreviations. If it encounters an unfamiliar unit designation, a warning message will be displayed indicating the unknown unit.

The values and units can be copied to the Clipboard using the Copy button, then pasted into other applications.

**Output Window**



Output Window

The Output Window is used to display the text output from the other data windows. It cannot be opened directly through either the main menu or button bar. It is a generic text editor used to store information created by the other data windows. It allows the user to perform all the basic editing functions of a typical editor. The Output Window has its own tool bar to access the common editing functions. These functions are: printing the text, saving to a file, cutting text, copying text, pasting text, font selection and closing the window.

The actual text in this window is not changed unless one of the output functions of the data windows is used. In such a case any existing text in the window is deleted and replaced by the new text. Since text in the window is not lost when switching from one material to another in the Material Name list, it makes it possible to store the output information from one material while using the data windows to compare it to the properties of a second material.

Once opened, the Output Window can also be used to store notes or write short documents. Just be sure to save or print the text before using one of the output functions of the data windows.

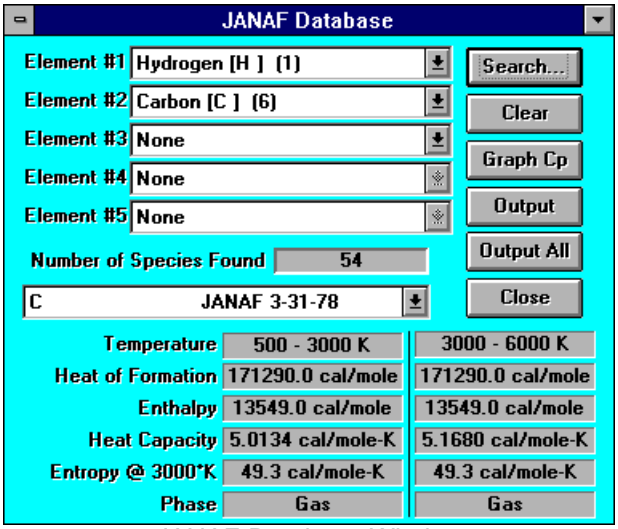
The text in the Output Window is not directly affected by the "Options Units" item in the main menu. Using the output functions in the Information Window will create a property list using the current Units setting. To get a list in different units, select a new units system then use the output function again to create a new output.

## Built-In Material Databases

TSP*X* includes two built-in material databases. These are accessible from the Built-In Databases submenu under the Databases menu and from the Toolbar; they do not show up in the Database menu list. These databases are derived from specific references that are not subject to change.

### JANAF Database Window

The JANAF Database Window provides access to the JANAF chemical species database. JANAF data includes information about species heat capacity, heat of formation, and more. The JANAF data used in TPS*X* was compiled by Acurex Corporation, Mountain View, California, and is a reduced version of the original data. These tables contain only certain properties, use curve fits to approximate the species heat capacity, and are optimized for use in developing ablation models for heat shield materials. The output created can be used as input to the Acurex program ACE, which creates material ablation models. The database cannot be viewed directly, but rather species of interest are found by searching the database for materials which contain user-defined elements.



JANAF Database Window

The search is performed by first selecting up to five elements in the drop-down list boxes. The program will prevent the same element from appearing in more than one box and at least one element *must* be selected to perform a search. Clicking the "Search" button starts TPS*X* scanning through the JANAF data file performing an "exclusive" search. That is, only those species that contain *only* the elements listed will be found. For instance, if carbon (C) and hydrogen (H) are selected, then the search will find C and $CH_4$ but will not find CO.

When the search is completed, the number of matching species will be displayed in the box and the names will be listed in the "Species" drop-down list box. The species are listed by chemical designation along with the source of the data and the date. The database may contain more than one entry for the same species, but from different sources. Selecting any of these species will display its properties. The properties are divided into two temperature regions; high and low temperature. The "Temperature" boxes show the range for each region. Below that are the properties for each region. The "Phase" boxes indicate the state of the species in that region. The property values are always displayed in the same SI units; the "Options Units" menu item has no effect on the JANAF Window.

Clicking the "Output" or "Output All" buttons opens the Output window and displays the currently selected species or all species found during the last search, respectively. The text in the window is fully editable, so you can make changes before printing it or saving it to a file.

The "Clear" button clears the element and species drop-down list boxes and the property boxes and prepares for a new search.

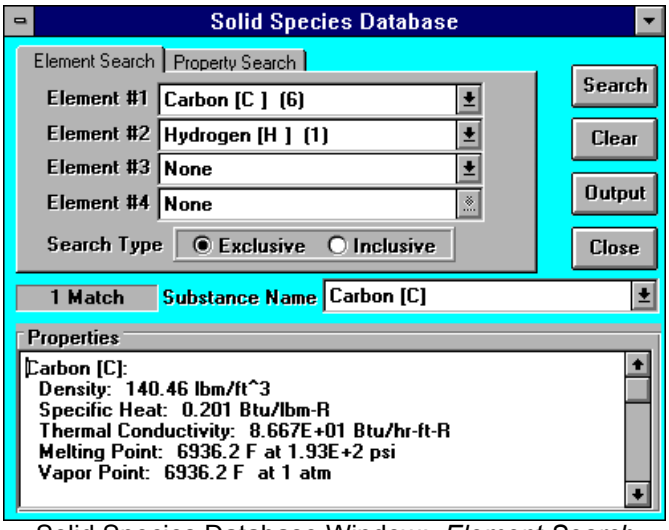
### JANAF Graph Window

The JANAF Graph Window displays a plot of the selected species heat capacity as a function of temperature. This window is opened by clicking the "Graph Cp" button in the JANAF window. Note that this window cannot be opened directly from the "View" menu, but must be opened after running a Search on the JANAF data. The graph uses to different colors to denote the two temperature regions and indicates the phase of the material. In cases where the two regions contain a phase change, there will generally be a discontinuity in the curve.

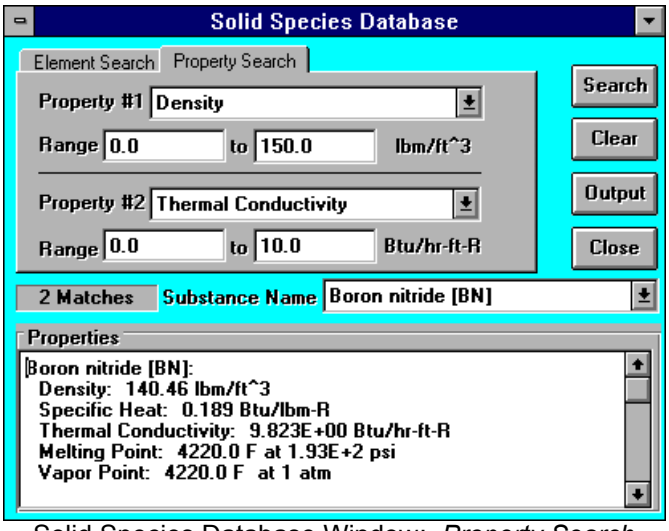
The "Options Units" menu item affects the heat capacity graph. When the "Default" setting is chosen, the graph shows heat capacity per mole (in cal/mole-K). When either the "SI" or "English" units are chosen the heat capacity per unit mass is plotted. This is accomplished by mutiplying by the mass per mole for the species.

The graph can be copied to the Windows Clipboard in a Metafile format from the "Edit Copy" menu item.

**Solid Species Database Window**




Solid Species Database Window: *Element Search*




Solid Species Database Window: *Property Search*

This provides access to a database of over 500 refractory materials compiled by Los Alamos Scientific Laboratory*. The database can be searched using two different criteria: constituent elements or material property. The element criterion searches for species that include the listed elements while the property criterion searches for elements whose properties fall within a given range.

For element searches, select one to four elements in the "Element" drop-down list boxes. The program will prevent the same element from appearing in more than one box and at least one element *must* be selected to perform a search. Selecting "All" in the "Element #1" box will list all the species in the database. Below the element boxes is the "Search Type" option. An "exclusive" search will find only those species which contain *only* the elements listed. An "inclusive" search is broader and will find all species which contain at least one of the elements listed.

For property searches, select one or two properties from the "Property" drop-down list boxes. At least one property must be selected. Enter the allowable range for the property in the two boxes beneath each property box *in the indicated units*. The indicated units will vary depending on which units system is currently active. The program will find those species which meet the property limits.

Click the "Search" button to start the search. The number of matches found will be indicated and the "Substance Name" drop-down list box will show the names of all the matching species. Select a name in the box to see a list of that's species properties in the scrolling text box.

The "Output" button will open the Output Window and write all the information about all the species found during the last search. The amount of text that can be stored in the Output Window is limited and this may generate a warning if there are too many species found in the search.

* "Thermal and Other Properties of Refractories", Technical Report Program No. R056, Dwayne T. Vier, Los Alamos Scientific Laboratory of the University of California, LA-5937-MS, April 1975.

## TPS*X* Main Menu

The Desktop Menu is the one of the most useful tools in the application and provides access to all the features of TPS*X*. Those options which apply to the active window will be enabled, those which do not apply will be disabled or "grayed out." Some of the menu options apply to all windows, but with slight differences in function. The menu options are listed below with a brief description of how they work.

### File Menu


The File Menu includes options for saving and printing information from the data windows. The options include:

**Save As... -** Saves the active text or graphics information to a file specified by the user. In the Information Window, the text in the Reference box is saved. In the Spread Sheet Window the entire data set is saved. In the Graph and JANAF Graph Windows the graph is saved as a Windows Metafile. In the Code Interface, Material List and Physical Constants Windows the entire contents of the text window is saved.

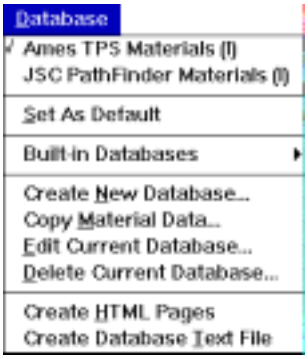
**Print... -** Prints the text or graphics from the active window to the selected printer. In the Information Window, selecting this command prints a standard form which includes all the properties at standard temperature and pressure, and the reference information. In the Spread Sheet Window selecting this command prints the entire spread sheet. In the Graph and JANAF Graph Windows, selecting print file prints the graph. In the Code Interface, Material List and Physical Constants Windows, this command prints the entire contents of the text window.

**Print Setup... -** Selects or sets up a printer. When this selection is made, a standard "Windows style" printer setup box appears. You can change the setup of the currently installed printer, or chose to setup up a different printer.

**Close -** Closes the active window without closing the TPS*X* application. When using any of the supplementary data windows, selecting File Close from the Desktop Menu will close the data window and its associated database. File close will not exit from the application.

**Exit -** Closes the TPS*X* application. This command will close any open windows and databases without saving any of the output from the Code Interface window or the Windows Clipboard.

### Database Menu




The Database Menu provides access to the various supplied and built-in databases. It also includes options to edit, create, delete and output the database information. The options include:

**Ames TPS Materials -** This selection opens the Ames TPS Materials database developed at NASA Ames Research Center.

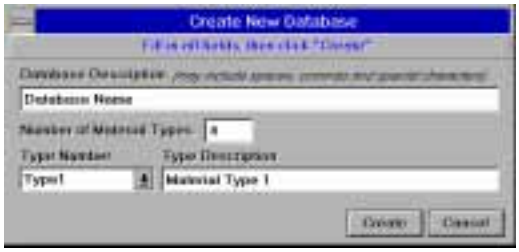
**JSC Pathfinder Materials -** This selection opens the JSC Patherfinder Material database.

**Other Databases -** When other databases are available they will also appear in this list. These may include user-created databases.

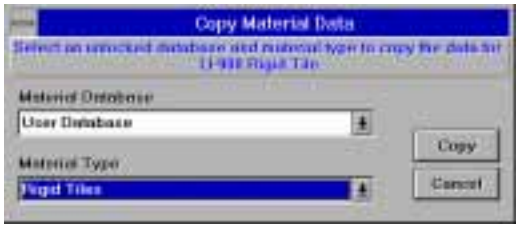
> ***Note:*** *the letter in parentheses to the right of the database name indicates if the database is locked (l) or unlocked (u). The databases that come with TPSX are locked and cannot be edited by the user. Any user-created databases will be unlocked.*

**Set As Default -** Sets the active database as the default. The default database is the one that is loaded when TPS*X* is started. If the default database is already active, this option is greyed out.


**Built-In Database**s **-** This submenu shows the built-in databases that come with TPS*X*. These databases always have their own special windows associated with them and include the JANAF database of chemical species and the refractory materials database compiled by Los Alamos.




**Create New Database... -** This command opens a dialog box that allows the user to create a new database. The user must enter a database name, the initial number of material types, and the material type names. The new database will appear in the Database menu but will not contain any information. Use the Editor or Copy Material Data commands to add new data.




**Copy Material Data... -** .Opens a dialog box that allows the user to copy the active material information to an unlocked database. This command requires that an unlock database exists in the data directory, if no such database exists, the command will be greyed out. Select the unlock database from the Material Database drop-down list, then the select on of the material types in that database. Once copied to an unlock database, the material information can be edited.

**Edit Current Database... -** .Starts the Database Editor and loads the active database. This option is not available for a locked database. See the Database Editor section for more information.

**Delete Current Database... -** .Deletes all the information associated with the current database. Any data deleted using this command CANNOT be recovered by TPS*X*. Exercise caution when using this command. The "default" database cannot be deleted.

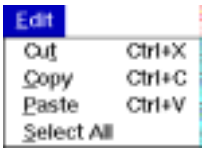
**Create HTML Pages -** .Creates a new subdirectory in the data directory called "html" and stores in it a set of HTML formatted pages containing the active database. These files are meant to be read using a World Wide Web browser like Netscape or Mosaic. The file "tpsxindx.htm" is the main "page" and can be viewed by using the "open local file" option in the Web browser.

***Note:*** *This option is meant as a convenience to the user who wishes to have access to the TPSX databases without the need to load the full TPSX program or for use on other operating systems not supported by TPSX. These files are* NOT TO BE PUBLISHED *on any Web site which allows general access to the information. The HTML formatted data is bound by the same restrictions mentioned in the non-disclosure form.*

**Create Database Text File -** .Creates a single ASCII text file containing all the data from the active database. The file can be edited or printed using any word processor that supports text files.

***Note:*** *This option is meant as a convenience to the user who wishes to create a hard copy of the TPSX database. The files are* NOT TO BE PUBLISHED *or distributed on any. The text file is bound by the same restrictions mentioned in the non-disclosure form.*

## Edit Menu




The Edit Menu includes the basic options to edit text and images within the data windows. In many of the text areas of TPS*X*, the Edit menu can be activated as a pop-up menu by clicking the *right* mouse button. The options include:

**Cut -** Cuts (removes) the selected text in the active window and places it in the Windows Clipboard. This command, along with copy and paste, allows the user to export data from these windows into

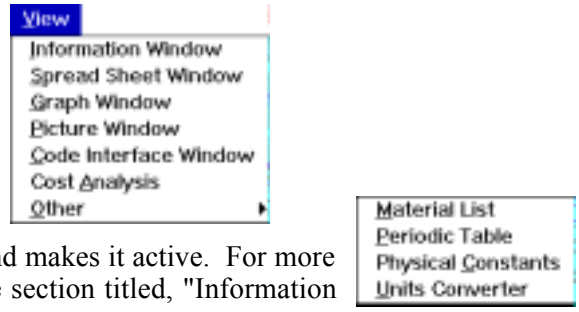
other programs. For example, the Code Interface output may be cut and pasted into another location for use as input into an analysis program.

**Copy -** Copies the selected text or graphic in the active window into the Clipboard. In the graph windows, the graph is placed in the Clipboard in a Windows Metafile format. In the Information Window, it copies any text selected in the Reference box. In the Spread Sheet Window, it copies the selected cells. In the Graph and JANAF Graph Windows, it copies the graph in Windows Metafile format. In the Picture Window, it copies pictures in Windows bitmap (BMP) format or Metafile format, depending on the picture type, In the Code Interface, Material List and Physical Constants Windows, selecting edit copy copies the selected text.

**Paste -** Pastes the contents of the Clipboard into the selected text area in the active window. Used with the copy and cut commands, this command will allow the user to export data and information from the TPS*X* application into other programs. For example, Code Interface output can be cut and pasted into a text editor for use as input data for an engineering analysis code.

**Select All -** Selects all the text in the text area of the active window. Selected text will be highlighted. This command provides a quick way of selecting large amounts of data for export to other programs

## View Menu




The View Menu is used to access the various data and supplementary data windows in TPS*X*. The Button Bar also provides access to these functions. The options include:

**Information Window -** Opens the Information data window, or brings it to the top of the desktop, and makes it active. For more information on how this window works, see the section titled, "Information Window."

**Spread Sheet Window -** Opens the Spread Sheet data window, or brings it to the top of the desktop, and makes it active. If the Graph window is opened and displaying data, then the corresponding data will be displayed in the Spread Sheet window. For more information about how this window works, see the section titled, "Spread Sheet Window."

**Graph Window -** Opens the Graph data window, or brings it to the top of the desktop, and makes it active. If the Spread Sheet window is opened and displaying data, then the corresponding data will be plotted in the Graph window. Additional menu choices are available to change the way in which the graph appears. For information on these features and how this window works, see the section titled, "Options Menu."

**Picture Window -** Opens the Picture data window, or brings it to the top of the desktop, and makes it active. If a picture is available for the material, it will automatically be displayed when the material name is selected. See the section titled, "Picture Window."

**Code Interface Window -** Opens the Code Interface data window, or brings it to the top of the desktop, and makes it active. The Code Interface Window is used to convert the material data into an input file for some engineering analysis programs. See the section titled, "Code Interface Window."

**Cost Analysis -** Opens the Cost Analysis window, or brings it to the top of the desktop, and makes it active. The Cost Analysis is used to estimate the per flight cost of insulation materials in reentry vehicle applications. See the section titled, "Cost Analysis Window."

**Material List -** Opens the Material List supplementary data window, or brings it to the top of the desktop, and makes it active. This option will display a list of all the material names in the current database. See section titled, "Material List."

**Periodic Table -** Opens the Periodic Table supplementary data window, or brings it to the top of the desktop, and makes it active. See section titled, "Periodic Table."

**Physical Constants -** Opens the Physical Constants supplementary data window, or brings it to the top of the desktop, and makes it active. This window offers a limited number of commonly used constants.

**Units Converter -** Opens the Units Converter supplementary data window, or brings it to the top of the desktop, and makes it active. This is a very useful tool for converting between English and SI unit systems or between any other similar units.

## Options Menu


The Options Menu lists certain user options that affect how TPS*X* operates and displays data. The options include:

**Units -** Selects one of three units systems for displaying property data. The option is saved when TPS*X* is exited. The options are:

**SI -** Sets the display of numeric values to standard SI units. All affected windows are updated immediately after selecting a Units option. Information and Spread Sheet Windows: data is displayed in standard SI units. Graph Window: graph is redrawn in SI units. JANAF Graph Window: the heat capacity data will be plotted in engineering SI units, rather than a per mole basis. This is done by multiplying the heat capacity by the per mole mass.

**English -** Sets the display of numeric values to standard SI units. All affected windows are updated immediately after selecting a Units option. Information and Spread Sheet Windows: data is displayed in English units. Graph Window: graph is redrawn in English units. JANAF Graph Window: the heat capacity data will be plotted in engineering English units, rather than a per mole basis. This is done by multiplying the heat capacity by the per mole mass.

**Default -** Sets the display of numeric values to their default units; these are the units in which the data appears in the database files. The default units may vary between materials. Information and Spread Sheet Windows: data is displayed in default units. Graph Window: graph is redrawn in default units. JANAF Graph Window: the heat capacity data will be plotted in a per mole basis, as it appears in the JANAF database.

**Show Picture -** A toggle indicating if the Picture window is opened automatically when a new material is selected. When checked, the Picture window is displayed if a picture exists. When unchecked, the Picture window must be opened explicitly from the toolbar or View menu. The option is saved when TPS*X* is exited.

**Show Banners -** A toggle indicating if the information banner about each database is displayed when the database is opened. If turned off the banners can be displayed using the About Current Database option in the Help menu. The option is saved when TPS*X* is exited.

**Button bar -** Selecting this options toggles the display of that part of the Desktop Toolbar which contains the window buttons. The option is saved when TPS*X* is exited.

**Grid -** When checked, a grid is displayed in the graph windows. The option is saved when TPS*X* exited.

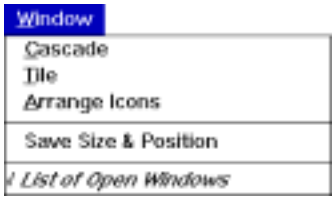
**Color -** When checked, the graph windows use solid color lines for each parameter set. When unchecked black lines and symbols are used. The option is saved when TPS*X* is exited.

**Semi-Log -** When checked the graph windows use a semi-log scale. when appropriate. When unchecked a linear scale is used. The option is saved when TPS*X* is exited.

**Zero Axis -** When checked the graph windows always show the zero axis of the ordinate. When unchecked the graph is scaled based on the data. This is useful for expanding the plot. The option is saved when TPS*X* is exited.

**Font... -** Opens a dialog box for selecting the display font. This font will also be used when the text is printed. This option only affects the Output and Spread Sheet Windows.

## Window Menu




The Window Menu controls the placement of the MDI child windows in the TPS*X* workspace and provides easly access to those windows. The options include:

**Cascade -** Organizes the open data windows, laying them one on top of another.

**Tile -** Moves and resizes the open data windows to make each one visible.

**Arrange Icons -** Organizes the icons of minimized windows at the bottom of the Desktop.

**Save Size & Position** - Saves the size and position of the main TPS*X* window. The next time TPS*X* is run, it will appear in the same location.

**Window (List) -** This part of the menu displays a list of all the opened windows. Clicking on the name of a window, restores it and makes it active.

## Help Menu


The Help Menu provides access to the TPS*X* Help system and other general information about the databases and TPS*X*. The options include:

**Help on Topic -** Selecting this option will automatically open the TPS*X* Help file and display the page pertaining to the currently active window, menu, button, etc. This has the same effect as clicking on the "Help" button in the Desktop Toolbar or pressing F1.

**Table of Contents -** This selection will open the TPS*X* Help file to the first page and allow the user to select where help is needed.

**Search for Help on. . . -** This selection will open a search dialog box and allow the user to enter the string to use for searching the TPS*X* Help file.

**Glossary -** Opens the Help file to the glossary pages. There are two glossaries in the TPS*X* Help File. One glossary is for terms used in TPS*X*. The second glossary contains material and property terms.

**About Current Database . . . -** Displays the banner information about the active database.

**About TPSX . . . -** Displays the About Box, system information and the registered user name.

# Database Editor

## Introduction

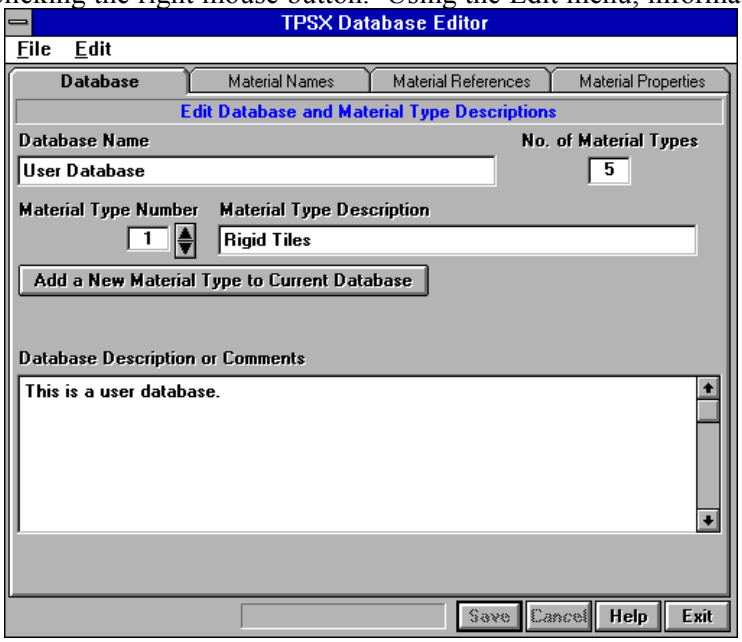
TPS*X* includes a built-in editor which allows the user to modify virtually any information in an unlocked (or user created) database. Users can change the name of the database or material types, add new material types or names, add and change material properties, and more.

The Editor is started by selecting the Edit Current Database command from the Database menu. While using the Editor, the other functions of TPS*X* are not available. After exiting the Editor TPS*X* will regenerate the binary data files associated with the database, if changes were made.

The Editor is composed of a main window, which includes a menu bar at the top and four command buttons at the bottom. A progress indicator is also located at the bottom of the window. The editing functions are accessed using the four tabbed forms. Each of these forms provides tools to edit specific aspects of the database.

## Main Editor Window

The menu bar includes a File and Edit submenu. The File menu has only one command; to exit the Editor. The Edit menu provides standard editing commands and can also be accessed in most fields by clicking the right mouse button. Using the Edit menu, information can be cut and copied within fields in the Editor, or to and from other applications.



Database Editor

At the bottom of the Editor window are four command buttons. These are:

The Save button is used to save current changes to the database. When data is entered or modified, it is *not* written into the database until the Save command is executed. The Save button is enabled only when changes are made to the information in the active tabbed form.

The Cancel button is used to remove any changes made, but not yet saved. The information in a tabbed form is reset to the original state when the Cancel command is executed. This command *does not* remove changes which have already been saved. The Cancel button is enabled only when changes are made to the information in the active tabbed form.

> ***Note***: *When changes are made to the data in a tabbed form, the data must be Saved or Canceled before switching to another tabbed form.*

The Help button opens the TPS*X* help file to the Editor information.

The Exit button closes the Database Editor and returns control back to the main TPSX window. If any changes have been made to information in the active tabbed form, the user will be asked to Save or Cancel those changes before exiting the Editor.

The Editor reads and writes data to and from the database files. During these processes the progress bar at the bottom of the window will indicate how much of the process has been completed. None of the editing functions are available while the program is reading or writing data to the files.

### Database Tab

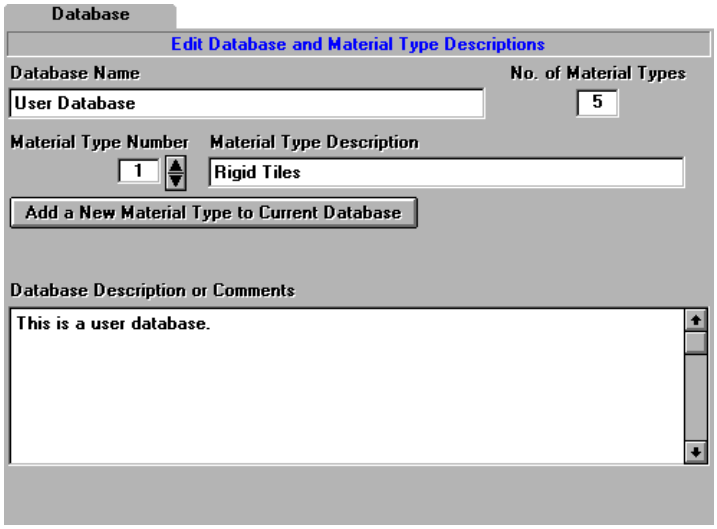
The Database tab provides access to general information about the database and material types. The Database Name, Material Type Description and Database Description fields can be edited.

The Database Name defines the name of the database and is the shown in the Database menu of TPS*X*. This field can include spaces and special characters.

The Material Type Description defines the names of all the material types. These are the names that are shown in the Material Type drop-down list box in the TPS*X* main window. Use the spin button to scroll through all the material types in the database.

New material types can be added to the database by clicking on the button provided. When a new material type is added, a default name will appear in the material types list and can be edited.

The Database Description is the text that appears in the Banner when the database is opened. This field can include any text, but should be limited to the amount of text that can appear in the available text area.



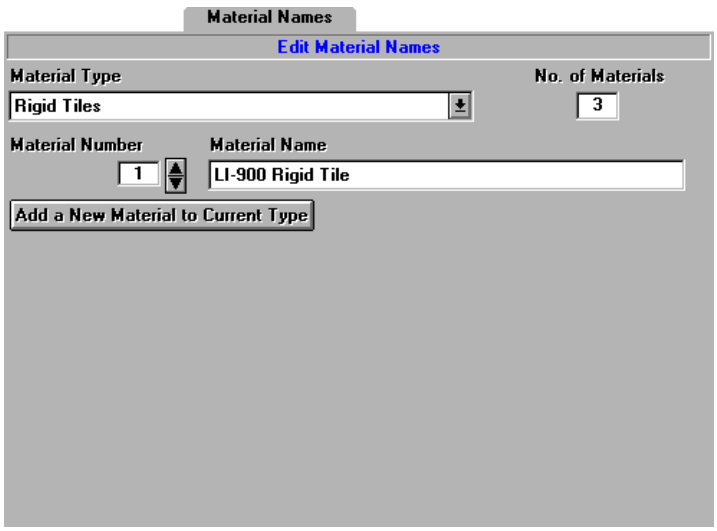

Database Tabbed Form

### Material Names Tab

The Material Names tab provides access to the material names. Only the Material Name field can be edited in this tab.

Selecting the Material Type will display the associated Material Names. The value next to the type box indicates the number of material names within that type. The spin button can be used to scroll through all the names.

New materials can be added by clicking the button. The new default material name will appear in the box and can then be edited. A new material *must* be added using this tab before any property data can be added.

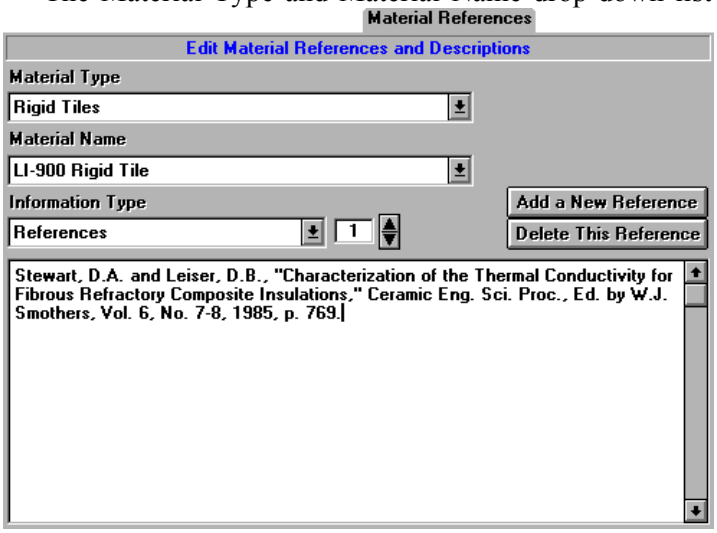



Material Names Tabbed Form

### Material References Tab

The Material References tab provides access to the reference, point of contact, description and summary of all the materials. Only the data in the text area can be edited.

The Material Type and Material Name drop-down list boxes are used to select the material to be edited. The Information Type defines the data that is displayed in the text area; this can be the Description, Summary, Point of Contact or References. The Description is the information which appears in the Information Window of TPS*X* and is included in outputs of the material data. The Summary is shown in the Material List Window of TPS*X* and should be limited to only a few sentences. The Point of Contact should include a name and contact information of the person responsible for the data. The References should include any published reference material. For the References information a spin button is provided to scroll through each reference. *Only one reference should appear in the text area.* Use the buttons to add a reference or delete the displayed reference.

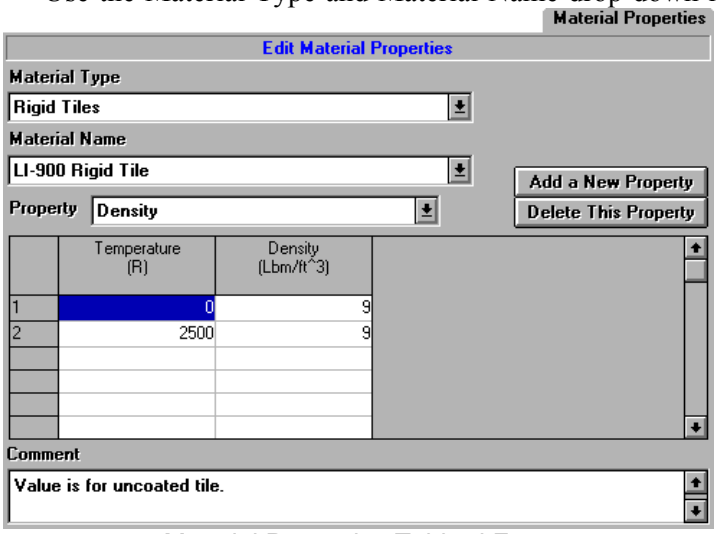



Material References Tabbed Form

### Material Properties Tab

The Material Properties tab provides access to the actual material properties. The information in the white cells of the spread sheet and in the Comment text area can be edited.

Use the Material Type and Material Name drop-down list boxes to select the material to edit. The Property list box lists all the properties currently in the database for the selected material. Selecting a property displays the data in the spread sheet and any comments in the Comment text area.




Material Properties Tabbed Form

Each cell in the spread sheet can be edited and new data can be added to the end of the list. Avoid leaving blank rows in the data when adding new information. The units displayed in the column headers correspond to the values originally entered in the database and cannot be changed. *It is the users responsibility to guarantee that the entered data corresponds to the units in the headers in each column.*

Data can be pasted into the cells from any other spread sheet program that copies data in a tab-delimited format, such as Microsoft Excel. The selection region must be at least as large as the data being pasted, i.e., the number of selected rows and columns should be the same as the number of rows and columns copied from the other application.

The text in the Comment area is used to provide any additional information about the property. This information is displayed in the TPS*X* Data and Graph Windows by clicking the "Note" button. It is also included in the outputs created from the Information Window.

Material properties can be added and deleted using the two buttons. The "Delete This Property" button will remove the displayed property from the database.

The "Add a New Property" button opens a dialog box where the user can enter information about a new property for the selected material. The information about the new property is defined in two or more steps. During any part of the procedure the Cancel button will stop the process without making changes to the database.

In the first step the user is asked to select the property to be added from the drop-down list. The Information box at the bottom of the window describes the property. The units for this property are selected from the Units drop-down list box. If the property is a function of one or more independent parameters, e.g., temperature or pressure, the number of dependent variables is selected using the spin button. Up to three independent parameters can be defined. If the property is a constant, the number if independent parameters should be zero.

Add Property: Step 1

Click "Next" to proceed to the next step to define the independent parameters. These are entered using the same procedure as the property itself. When entering more than one independent parameter, the value on which the property is "most" dependent should be entered first and the "least" dependent last. For example, if a property is a function of temperature and, parametrically, a function of pressure, then temperature would entered first and pressure second.

Add Property: Step 2

***Note***: *Some properties and independent varaiables are non-numeric in nature, e.g., surface finish; these properties have allowable "values" in TPSX. When appropriate, these allowable values are shown in the Information text box. It is the users responsibility to see that property data entered conforms to these requirments.*

The final step displays a description of the property and units. If any of the information is not correct, use the "Back" button to return to the appropriate step and change the necessary data. Clicking the "Finish" button will add the new property and return to the Material Properties tab form. A blank spread sheet with the appropriate property headers will be displayed and data can be entered into the cells.

Add Property: Final Step

**Creating a Locked Database**

The Editor only works on user defined, or unlocked, databases. "Locking" a database prevents any further changes in the data and can be useful when distributing data that should remain unaltered. TPS*X* uses two encrypted, binary files to store the database information; these files cannot be altered without destroying all the data in the file. These two files are the index file (*.IDX) and the data file (*.BIN). A locked database consistes of only these binary files. User created, unlocked databases store the data in two or more standard ASCII text files, as well as the binary files. These text files are the ASCII index (*.TPS) and ASCII data (*.CSV) files. Each

unlocked database will have one *.CSV file for each material type. TPS*X* automatically regenerates the binary files after the text files have be modified, so the two sets always contain the same data.

To turn an unlocked database into a locked one exit TPS*X* then delete, or move, the associated text files from the database directory. The user-generated TPS file will have the name "USERxx.TPS", where "xx" is a number from 01 to 99. The data files will have the name "USERxxyy.CSV", where "xx" is the same number as in the TPS file and "yy" is a number from 01 to 99. Once deleted, the text files *cannot* be recreated by TPS*X*.

# Appendix A: TPS*X* Installation and System Requirements

**System Requirements**

TPS*X* comes on at least four diskettes in a compressed format (Diskette Version) or as a single self-extracting file (Network Version). You must follow the instructions below to install TPS*X* correctly. For the program to run properly, your computer system must have the following minimum configuration:

- IBM or compatible PC with a 386 processor or higher (a 486 is strongly recommended), or a UNIX or Macintosh system running Insignia Solutions' *SoftWindows*
- Windows 3.1, Windows for Workgroups or Windows 95
- High density (1.44MB) 3_" floppy drive
- 8 megabytes of memory (RAM)
- a hard disk with at least 10 megabytes of free space
- VGA resolution monitor with 256-color support (super-VGA is strongly recommended)
- a Windows-compatible mouse is strongly recommended but not required

Follow the appropriate instructions below for the version you received. If you have TPSX on diskettes, use the Diskette Version instructions. If you downloaded the self-extracting file from the TPS*X* Web site, follow the Network Version instructions.

**Installation Procedure (Diskette Version)**

1) start Windows in Standard or Enhanced mode (the installation program will not run in in Windows 3.1 in Real mode)
2) close any and all running applications (including screen savers and network programs)
3) place Disk 1 in the floppy drive
4) from the Program Manager "File" menu select "Run..."
5) enter "A:\SETUP" or "B:\SETUP" depending on which drive the diskette is in
6) follow the on-screen instructions to install TPS*X*

**Installation Procedure (Network Version)**

1) start Windows in Standard or Enhanced mode (the installation program will not run in in Windows 3.1 in Real mode)
2) close any and all running applications (including screen savers and network programs)
3) copy the self-extracting file(s) to an empty temporary directory (e.g., "C\:TEMP")
4) from DOS prompt or from a DOS window, type the name of the self-extracting file(s) and hit Enter (e.g. "`tpsxv11.exe <ENTER>`"), this will extract all the necessary installation files to the temporary directory
5) return to Windows
6) from the Program Manager "File" menu select "Run..."
5) enter "C:\TEMP\SETUP.EXE" (substitute the name of the temporary directory if necessary)
6) follow the on-screen instructions to install TPS*X*

The installation procedure will create a TPS*X* program group containing the TPS*X* program icon. If you wish you may move the program icon to another group and delete the TPS*X* program group after installation. Double-click on the TPS*X* icon to start the program.

If TPS*X* fails to install properly, see the Installation Errors appendix. If it installs properly but does not run, see the Run-Time Errors appendix.

**Registering TPS*X***

The first time TPS*X* is executed it will display a dialog box asking for the User Registration Name and User Registration Number. Enter both of these values EXACTLY as they appear in your registration information. If you do not have a valid User Name and User Registration Number, contact TPS*X* support to request one. TPS*X* **will not run** if a valid registration is not entered.

### Installation Notes

The installation routine copies necessary files to the application directory specified by the user, the \WINDOWS directory and the \WINDOWS\SYSTEM subdirectory. The files copied to the Windows directories are "Dynamic Link Libraries" (DLL) required to run TPS*X*. If these files already exist, the installation program will copy the DLL's from the TPS*X* distribution ONLY if they are newer versions. (See Run-Time Errors appendix for more information.) The installation routine will NOT modify the AUTOEXEC.BAT, CONFIG.SYS, WIN.INI or SYSTEM.INI files.

# Appendix B: Installation Errors

The following are errors that may occur during the installation of TPS*X*. If you experience and error not described here, please contact Technical Support (see Appendix D).

**Note:** *The errors and fixes listed here are geared for Windows 3.1 and Windows for Workgroups 3.11 users. If you have problems installing TPSX under Windows 95, please contact TPSX support for help.*

**Problems with Windows Shell Programs**

If you are using a Windows desktop shell other than the default Program Manager (such as Norton Desktop for Windows), the installation process may display an error after completion. This error message is most likely just informational and the installation will be successful. If TPS*X* does not function properly after receiving such an error message, then start Windows with the default Program Manager shell and re-install TPS*X*. You can set the startup shell by editing the line "`shell=`" in the [boot] section of the Windows SYSTEM.INI file. To use the Program Manager shell, the line should read "`shell=progman.exe`".

**Link Library Errors**

TPS*X* uses the latest versions of several Windows DLL's (dynamic link libraries). These will be copied onto your system during the installation. If TPS*X* fails to install because the setup program warns that the current COMMDLG.DLL library, or another DLL, is in use, then perform each of the following steps in order until TPS*X* installs correctly.

1. Check your WINDOWS directory and make sure that the file COMMDLG.DLL is NOT there. This file should only be in the Windows SYSTEM subdirectory (where TPS*X* correctly installed it). If you do find the COMMDLG.DLL file in the Windows directory, delete it and try running TPS*X* again.
2. If step 1 fails: Close ALL running programs, including screen savers and network programs. Re-install TPS*X*.
3. If step 2 fails: If you are running a desktop shell other than the Windows Program Manager (such as Norton Desktop for Windows), set the shell environment to the Program Manager (as described above). Follow step 1 again with the Program Manager running and re-install TPS*X*.
4. If step 3 fails: You will need to manually uncompress and copy the DLL to the Windows SYSTEM subdirectory. First check the date of the COMMDLG.DL_ on diskette 1 of the TPS*X* installation and make sure it is newer than the COMMDLG.DLL file in your Windows SYSTEM subdirectory. Then follow the appropriate procedure below.

   If your Windows program resides on C: drive and is in the standard WINDOWS directory then follow this procedure:

   - Exit Windows and return to the DOS prompt.
   - Place the TPS*X* installation diskette 1 in the floppy drive and type A: or B:, depending on the drive designation.
   - Type "`FIXCOMM`" from the DOS prompt. This will run a batch file that will copy the correct DLL to the Windows SYSTEM subdirectory.
   - Restart Windows and install TPS*X*.

   If your Windows program does NOT resides on C: drive or is in a directory other than WINDOWS, then follow this procedure:

   - Exit Windows and return to DOS.

- Place the TPS*X* installation diskette 1 in the floppy drive.
- Copy the files COMMDLG.DL_ and EXPAND.EXE to a temporary directory on your hard disk.
- From the temporary directory type "EXPAND COMMDLG.DL_ COMMDLG.DLL". This should create the COMMDLG.DLL file.
- Copy the file COMMDLG.DLL to your Windows SYSTEM subdirectory.
- Restart Windows and install TPS*X*.

5. If step 4 fails: I'm out of suggestions. You may have a much older version of Windows. Try re-installing Windows.

# Appendix C: Run-Time Errors

The following describes some errors that can occur while running TSP*X*.

**Problems with Link Libraries and OCX's**

The libraries which the TPS*X* installation routine copies to the Windows SYSTEM subdirectory are required for TPS*X* to run properly. These are the "OCX" files and the "DLL" files. TPS*X* uses the latest versions of these files. If you get an error, when you run TPS*X*, that the program requires a newer version of a DLL or OCX then one of the following is probably the problem.

1. You may have installed a program AFTER TPS*X* which copied an older version of a library into the Windows SYSTEM subdirectory. Some installation routines do NOT check the version or date of a file before over-writing it. If you suspect this is the problem, then re-install TPS*X* to copy the latest versions into the SYSTEM subdirectory.
2. If re-installing TPS*X* does not solve the problem, then it's possible that older versions of the libraries have been incorrectly placed in the WINDOWS directory. Most library files should be placed in the Windows SYSTEM subdirectory. To solve this problem, locate the offending DLL or OCX file in the Windows directory and delete it. A program that does not find a necessary library file in the Windows directory will automatically look in the SYSTEM subdirectory for a file with the same name and use that one.
3. If the problem persists, then you may have a corrupted library file or installation diskette and you will need to obtain a replacement. Or you may have an older or corrupted version of Windows.

**TPS*X* Not Finding Necessary Files**

If you get an error from TPS*X* warning that the program could not locate a particular data file, then one of the following may have occurred:

- You may have moved TPS*X* from it's original (installed) location. TPS*X* maintains a file called TPSX.INI in the TPS*X* directory. This file contains the location of the data files. If you move TPS*X* to a new directory or drive, this file will point to the wrong location. **Solution:** delete the TPSX.INI file and re-start TPS*X*; a new TPSX.INI file will be created with the correct data file location.
- Some of the data files may have been moved or deleted from the TPS*X* directory. **Solution:** re-install TPS*X* from the original distribution diskettes.
- You may have a bad set of distribution diskettes which did not contain all the necessary data files. Some earlier Alpha and Beta versions of TPS*X* were missing some data files: **Solution:** contact TPS*X* Technical Support (see Appendix D) for updated distribution diskettes.

**Warning About Bad Data File**

If, while reading a data file, TPS*X* finds a line that it cannot understand it will display a warning message to the user. You can just click the "OK" button to clear the message. Usually this is the result of a typo in the data file. While this is not a fatal error, it may make some of the property data unavailable. The warning message may indicate the file and line in which the error occurred. **Solution:** report the message TPS*X* Technical Support (see Appendix D) so the data file can be corrected.

## Appendix D: Technical Support

Because the developers of TPS*X* are engineers and scientists at NASA with a variety of research projects and other tasks, technical support can only be provided on a "time available" basis. With this in mind, please report errors, comments, suggestions or questions to:

| | |
|---|---|
| Mail: | **TPS*X* Support**<br>**M/S 234-1**<br>**NASA Ames Research Center**<br>**Moffett Field, CA 94035-1000** |
| FAX: | **(650) 604-0487** |
| E-Mail: | **tpsx-support@asm.arc.nasa.gov** |
| World Wide Web: | **http://asm.arc.nasa.gov/tpsx/**<br>*the TPSX Web site has the latest information on versions and bugs, and includes a Comment/Bug report form* |

No direct phone support is provided. Please do not call for support.

When reporting errors please be specific (i.e., completely describe the error and how it can be reproduced), provide a description of your computer system (e.g., CPU, memory, Windows version, DOS version, etc.) and listings of the AUTOEXEC.BAT, CONFIG.SYS, WIN.INI and SYSTEM.INI files. Also provide a mail address, FAX number or Internet address if you want a reply.

# Appendix E: TPS*X* Program and Data Files

*(Much of this information applies only to the 16-bit version of TPSX)*

TPS*X* requires a number of files in order to work properly. All of these files are copied to the hard disk during installation. Some of the files are necessary for the basic operation of the program, such as the executables (EXE), dynamic link libraries (DLL) and Visual Basic custom control libraries (OCX). The remaining files contain data that TPS*X* accesses during operation. If any of these files are missing or corrupted, TPS*X* will either not run at all or display error messages when running. The following describes the different files and their function.

**Executable Files**

TPS*X* requires two separate executable (EXE) files. The TPSX.EXE is the main program executable located in the TPS*X* directory. The other is called GSW.EXE and is located in the Windows SYSTEM subdirectory. This program is called the Graphics Server and it is started automatically whenever TPS*X* is run. The Graphics Server is part of Visual Basic and makes it possible for TPS*X* to display graphs of material properties. When running, the Graphics Server appears as an icon at the bottom of the Windows screen. The program should *not* be closed while TPS*X* is running as all graphing functions will be inaccessible.

**Dynamic Link Libraries and Custom Controls**

The dynamic link libraries (DLL) are files that contain subroutines accessed by the program at run time. There are three DLL's used by TPS*X*. The VBRUN300.DLL is a library of routines associated with Visual Basic. These routines are used to create the standard Windows "look and feel". The Graphics Server has it's own library, GSWDLL.DLL. Both of these files are located in the Windows SYSTEM subdirectory. The file TPSXFORL.DLL is a library of FORTRAN routines used by TPS*X*. This link library is stored in the TPS*X* directory. Another class of libraries are the Visual Basic custom controls (OCX). These provide enhancements to the standard Visual Basic link library and are stored in the Windows SYSTEM subdirectory.

**Help File**

TPS*X* contains a single help file, TPSX.HLP. This file is in the standard Windows Help format and is stored in the TPS*X* directory. The help file can be accessed from with TPS*X* or directly by double clicking on the help icon in the TPS*X* program group.

**TPS*X* Data Files**

The remainder of the files contain data accessed by TPS*X* and are all located in the TPS*X* directory. These files include the material database information, supplementary data and images.

The information for each database is stored in two binary files. The index file (*.IDX) contains general information about the entire database. The data file (*.BIN) contains all the material property data. Both files are necessary in order to access the data.

Unlock, or user-created, databases have additional text file associated with them. The text index file (*.TPS) contains general information about the database and pointers to the other associated files. The data files (*.CSV) contain the data in a text format, there is one data file for each material type associated with the database. The CSV files are stored is a "comma separated value" format which can be read using a standard text editor or spread sheet program. These text files are not actually used by TPS*X*, but rather the binary equivalent files (*.IDX and *.BIN) are created each time these files are changed. Deleting the *.TPS and *.CSV files essentially turns the unlocked database into a locked database.

Other file associated with the material database is the picture file. This file is formatted as a Microsoft Access database (*.MDB). The images are accessed by reference and are not incorporated into the binary data files.

The other data files are those associated with the supplementary data windows. The JANAF data (JANAF.DAT) is stored in a compressed, binary format. The solid species database is stored in a text file (REFRACT.CSV). The ELEMENTS.MDB contains data used in the periodic table window. The REDUCESI.CSV contains unit conversions used throughout TPS*X*. The PROP.CSV file contains the definitions of the property names and physical constants used in TPS*X*.

**TPSX.INI File**

TPS*X* also maintains an file called TPSX.INI in the program directory. This file stores the location of the program and data, the name of the default database (the database which loads when TPS*X* starts) and the settings of the toggles in the Options menu. This file is created using defaults the first time TPS*X* is run. If the location of the program or data is changed, it will be necessary to delete this file so that TPS*X* will create a new one with the proper settings. The user registration information is also stored in the TPSX.INI file in an encrypted format. If this file is deleted, it will be necessary to reenter the User Registration Name and User Registration Number.

## Glossary of TPS*X* Terms

ACE - Aerotherm Chemical Equilibrium code. A computer program developed at Acurex Corporation to generate ablation (B') models for materials. The program uses inputs from a JANAF database and the resulting models can be used in CMA and the ASC codes.

ASC (ASCC) - The ABRES (Advanced Ballistic Re-Entry System) Shape Change Code. A computer program developed at Acurex Corporation to predict the thermal response of ablating heat shield materials during hyper-sonic atmospheric reentry.

Button Bar - The part of the Desktop Toolbar which contains the buttons for opening the data windows.

Child Window - A Multiple-Document Interface (MDI) window which exists on the desktop.

Clipboard - The Windows Clipboard provides temporary storage for information you want to transfer from one application to another. "Copying" text or graphics places them in the Clipboard. "Pasting" copies the contents of the Clipboard into the active application.

CMA - The Charring Material Ablation code. A computer program developed at Acurex Corporation to model the 1-D thermal response of charring/ablating materials.

Code Interface Button - The button on the toolbar which opens the Code Interface material window.

COSMOS/M - A finite element analysis system created by Structural Research and Associates Corporation.

CST - "Competitively Sensitive Technology", A phrase used to describe research and/or data which are not yet publicly available and may be considered to have significant technological potential for the United States. TPS*X* is available in CST and non-CST versions.

Database Menu - Allows the user to select the database from which to work.

Data Windows - The "child" windows within the TPS*X* desktop which display material property data and supplementary data.

Desktop - The main TPS*X* interface which holds the data windows, menus and toolbar.

Drop-down List Box - A box that presents a list of options when you select the arrow in the square box at the right.

Edit Menu - Provides editing options for those windows which allow these actions.

File Menu - Provides file opening and saving options.

Graph Button - The button on the toolbar which opens the Graph material window.

Help Menu - Provides help options.

Information Button - The button on the toolbar which opens the Information material window.

JANAF - A collection of thermal properties for chemical species (sometimes referred to as JANNAF). The JANAF data is accessible from the JANAF supplementary window. The JANAF Thermochemical Tables were originally compiled in the early 1960's by The Dow Chemical Company, Midland, Michigan and technically assisted by The Joint Army-Navy-Air Force-ARPA-NASA (JANAF) Thermochemical Working Group. The purpose of the project was to create a single source of "best available data" for use by the entire aero-space industry. The original use for the tables was in the development of rocket propellants. The JANAF data spans many volumes and hundreds of species. The JANAF data used in TPS*X* is a reduced version of the original which was created by Acurex Corporation, Mountain View, California. These tables contain only certain properties and use curve fits to approximate the species heat capacity. These tables are optimized for use in developing ablation models for heat shield materials.

JANAF Button - The button on the toolbar which opens the JANAF supplemental window.

MASCC - The Maneuvering ABRES (Advanced Ballistic Re-Entry System) Shape Change Code. A computer program developed at Acurex Corporation to predict the thermal response of ablating materials on reentry vehicles at angle of attack. A version of the ASC code.

Material List Box - The box in the desktop toolbar where the user selects the name of the material.

Material Data Windows - Data windows in the TPS*X* desktop which display property information related to the selected material.

Material List Button - The button on the toolbar which opens the Material List supplemental window.

Material Type List Box - he box in the desktop toolbar where the user selects the type of material.

Message Area - The area on the desktop which displays useful messages.

Metafile - A Windows vector format for storing graphic images. Metafile names are usually given a WMF extension.

Multiple-Document Interface (MDI) - A standard for displaying multiple windows of information in a single application.

Options Menu - Provides various options dependent on the active window.

Pathfinder - The PathFinder Thermophysical Property Data was compiled for NASA Johnson Space Center. One of the objectives of the PathFinder program was to develop the technology required to design high energy aerobraking (HEAB) vehicles for transportation between Earth and neighboring planets. An objective of this particular task was to perform a thermophysical property literature survey on materials that could potentially be used for HEAB thermal protection systems.

Periodic Table Button - The button on the toolbar which opens the Periodic Table supplemental window.

Physical Constants Button - The button on the toolbar which opens the Physical Constants supplemental window.

Picture Button - The button on the toolbar which opens the Picture material window.

Solid Species Data Button - This button on the toolbar opens the Solid Species Data window.

Spread Sheet Button - The button on the toolbar which opens the Spread Sheet material window.

STM - The designation for the Thermal Protection Materials and Systems Branch as NASA Ames Research Center. The research in this branch supports the development, manufacturing, testing and modeling of thermal protection materials and systems for use on space craft and planetary probes.

Supplementary Data Windows - Data windows in the TPS*X* desktop which display general information unrelated to the selected material. This information is available whether or not a material database is loaded.

Title Bar - he bar at the top of the desktop which displays the name of the current material database.

Toolbar - The bar beneath the menu bar which allows the user to select a material type and material name from two drop-down list boxes and has buttons to directly access the data windows.

TPS - Thermal Protection System: A system designed to protect a vehicle (spacecraft or aircraft) from the thermal loads associated with hyper-sonic flight.

Units Converter Button - he button on the toolbar which opens the Units Converter supplemental window.

View Menu - Provides access to all the data windows. Alternately the Toolbar buttons can be used to open the data windows.

Window Area - That area on the desktop where the child data windows are displayed.

Window Menu - Provides control over the open data windows.

## Glossary of Material and Property Terms

Ablating Temperature - Temperature at which a material begins to lose mass causing surface recession.

ACC - Advanced Carbon/Carbon composite. ACC is an improved version of RCC, exhibiting greater strength, increased resistance to oxidation, and reduced fabrication time.

AETB - Alumina Enhanced Thermal Barrier. AETB is a low density composite insulation made from small diameter silica and alumina fibers and larger aluminoborosilicate fibers.

AFRSI - Advanced Flexible Reusable Surface Insulation.

B-Prime (B') - A non-dimensional mass loss rate (or blowing rate) for ablating materials; generally a function of temperature, pressure and heat transfer coefficient. B' tables are used in the ASC and CMA codes to model material ablation.

Blowing Correction - A coefficient used in the ASC and CMA codes to correct the heat flux to the surface during mass loss.

Carbon/Carbon - High-temperature TPS material made of carbon densified carbon cloth, often used in ablating heat shields.

Charring Temperature - Temperature at which a material begins to decompose (or pyrolize) beneath the surface.

CFBI - Composite Flexible Blanket Insulation. A flexible composite insulation system consisting of an outer layer of aluminoborosilicate fabric, followed by alumina mat insulation, and alternating layers of aluminized polyimide film and aluminoborosilicate scrim fabric.

Coating - Refers to whether or not a material is coated with a specified thermodynamic coating.

Coefficient of Thermal Expansion - A measure of the volume change in a material due to a change in temperature.

Compressive Strength - The compressive strength at which a material begins to yield.

Density - The mass per unit volume of a material. Char Density refers the density of an ablating material after the ablation process.

Direction - The direction, parallel or normal, to the plane of the sample or fibers along which the material properties are measured.

Emissivity - The ratio, over all wavelengths, of the radiation emitted from a real surface to the radiation emitted from a black body at a the same temperature. In many instances the emissivity is considered equal to the absorptivity for a given material.

Eutectic Temperature - The temperature at which a composite material will form at least some melting liquid. This temperature is often lower than any of the melt temperatures of the constituent materials.

FRCI - Fibrous Refractory Composite Insulation. A composite insulation made from small diameter silica and larger aluminoborosilicate fibers

Heat of Formation - The change in heat content when one mole of a substance is formed from its constituent elements in their standard states.

Heat of Fusion - The enthalpy difference between the liquid and solid phases of a material at the melting temperature.

Intrinsic Roughness Height - Height of the roughness elements on the surface of the material. This property is used in the ASC and CMA codes.

Melting Temperature - Temperature at which the bulk material becomes liquid.

Multiple Use Temperature Limit - The maximum temperature a material can withstand without significant degradation in performance or material properties.

Plies - The number of layers of the material that are stacked-up to make the sample. If ply number is not specified, which is the default setting, than there is only one layer of the material in the sample.

Poisson's Ratio - In general, the ratio of the strain in the direction of an applied stress to the strain perpendicular to the stress. For most materials Poisson's ratio is in the neighborhood of 0.25 to 0.35.

Pyrolysis - The in depth decomposition of a material under high temperatures. This often results in "out gassing" through the surface of the material.

RCC - Reinforced Carbon/Carbon composite. A low modulus rayon precursor-based fabric with a filled phenolic resin. Currently outdated by ACC.

RCG - Reaction Cured Glass coating. A 12-15 mil thick fully dense waterproof glass coating with a very low thermal expansion coefficient and a high thermal shock resistance.

Shear Modulus - Ratio of the shearing strain to the shear stress. Also: modulus of rigidity.

Shear Strength - The shear stress at which the material begins to yield.

Silicon Carbide - High-temperature heat shield material.

Single Use Temperature Limit - The minimum temperature at which a material will "fail" or no longer perform properly.

Specific Heat - The amount of energy given to a unit mass of a material per unit rise in temperature.

TABI - Tailorable Advanced Blanket Insulation.

Tensile Modulus - Ratio of the tensile strain to the tensile stress. Also: Young's modulus or modulus of elasticity.

Tensile Strength - The tensile stress at which the material begins to yield.

Thermal Conductivity - The ratio of the heat flux to the temperature gradient, according to the Fourier law. Char Thermal Conductivity refers to the thermal conductivity value after the ablation process of an ablator material.

TUFI - Toughened Uni-Piece Fibrous Insulation composite surface. A porous composite of the insulation and coating material impregnated into the insulation surface rather than a fully dense coating resting on top of the insulation.

Turbulent Roughness Height - The apparent height of the roughness elements on the surface of the material in turbulent flow. This property is used in the ASC and CMA codes.

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